CHAPTER 5

FLOOD LOSS REDUCTION MEASURES

5-1. General.

a. A broad range of potential flood loss reduction measures and performance standards should be addressed in planning investigations. These measures may be structural or nonstructural.

b. This chapter defines a broad array of measures for reducing flood related losses in interior areas. Emphasis is on the applicability of each measure as it relates to interior areas. Hydrologic analysis aspects of the measures are also presented. The measures have been classified for discussion purposes into:

(1) physical measures at line-of-protection,

(2) physical measures remote from line-of-protection, and

(3) nonstructural measures.

Physical measures at the line-of-protection include the main levee or wall (line-of-protection), gravity and pressure outlets; interceptor sewers, detention storage, and pumping facilities. Physical measures remote from the line-of-protection include diversions, channels, reservoirs (detention or retention basin), and interior levees or walls. Nonstructural measures include permenent measures for existing structures, measures to manage future development, and flood warning-emergency preparedness actions.

5-2. Physical Measures at Line-of-Protection.

a. Main Levees or Flood Walls. These measures comprise the line-of-protection that prevent direct flooding from rivers, lakes, or tidal waters. Implementation of these barriers creates the interior area by intercepting interior runoff and seepage at the line-of-protection.

(1) Major alignment considerations of the line-of-protection should be:

(a) minimization of the interior area contributing to runoff with proper locations of tie back levees, use of pressure conduits, and diversions out of the area;

(b) right-of-way and preservation of natural conveyance and storage areas; and

(c) minimization of volume of wave overtopping design freeboard of the line-of-protection so that if it occurs it will take place in a planned manner (e.g., least damaging, safe location).

(2) Minimum interior facility capacity through the line-of protection shall be provided as defined in paragraph 3-2b.

(3) Flood warning-preparedness plans should be considered as necessary components to the line-of-protection for urban areas. Associated actions, described later, may reduce the threat of catastrophic loss of life and property should failure occur in the line-of-protection.

b. Gravity Outlets.

(1) Gravity outlets are defined as culverts, conduits, or other openings (through the line-of-protection) that permit discharge of interior waters through the line-of-protection. The size of interior detention basins at the intake of the gravity outlet are based on the economic, environmental, and social aspects associated with the outfall ditch, gravity conduit, and ponding area analyzed as a collective system. The size selection must be based on the functional operation of the outlet for a range of expected events and not on a single design event.

(2) Where possible, gravity outlets should be located at or near where the line-of-protection intersects the natural or existing conveyance system or detention area. It is normally more feasible to provide one large gravity outlet than several smaller ones. This may require an interceptor system along the line-of-protection.

(3) Gravity outflow rating functions are normally required to assess the outlfow conditions of the major outlets. Rating functions should be developed for primary gravity outlets but may be combined for secondary outlets. Interior area discharge rating curves for gravity outlets are determined for a range of low and high tailwater conditions.

(4) Gravity outlet operational criteria are normally determined in the design level of study. Existing gravity outlet operation criteria should be obtained from the agency responsible for operating the interior system. Analysis of modified operation procedures is part of the plan formulation process. Normal operational criteria will be to release water to attempt to follow the lowering of the interior stages while maintaining a small positive head. The lag time between interior and exterior peak stages may be a critical factor in the operation specifications.

(5) Detention storage near the line-of-protection can reduce the capacity needed for outlets. Conveyance channels must be sized appropriately to assure that design flows are conveyed to gravity outlets, pumping stations, and/or detention basins at acceptable elevations. Flood forecasting measures may facilitate gravity outlet operation.

(6) The specific dimensions, invert elevation, headwalls and tailwalls and gate configuration of the gravity facility are normally considered to be determined by hydraulic design studies and are therefore not discussed in detail in this manual.

c. Detention Areas Adjacent to Line-of-Protection.

(1) The use of detention areas can significantly reduce the gravity outlet and pumping station size and costs. A detention basin may also increase the reliability of the system by providing additional time for appropriate operation before damaging water levels occur. A detention area may be natural or excavated sumps, or induced temporary ponding on vacant lots or areas, and streets and parks. Only a few areas are typically available or selected, and an interceptor system to collect and convey runoff along the line-of-protection is generally required.

(2) Topography, existing conveyance patterns, and land use usually govern the approximate locations of detention areas. Detention areas are normally located adjacent to the gravity outlet or pumping station, but may be remote from these facilities, connected by appropriately sized channels.

(3) Implementing nonstructural measures for surrounding structures to gain incremental storage versus increased capacity of gravity outlet or pumping facilities may be warranted in urban settings.

(4) Detention basins can be designed to be environmentally attractive and contribute to community social goals in urban areas when used as parks and open spaces during periods when not needed for runoff storage.

(5) Management of the functional integrity of the detention basin by preventing development encroachment and subsequent loss of storage capacity is critically important. Local agency agreements should specify requirements for maintenance of detention basin functional integrity throughout the project life.

(6) Hydrologic analyses should assess the impact of future development (volume of runoff) in terms of additional storage requirements of the detention basin.

d. Pump Stations.

(1) Pumps are designed to lift storm water and other interior flows over or through the line-of-protection to the exterior river, lake, or coastal area. Pump stations operate to reduce duration of ponding when flow through gravity outlets is precluded or impeded by high exterior stages. Consideration should be given to setting these elevations so that the pumps may be operated at least once or twice annually for maintenance and testing purposes. Pumps may be used for storm runoff, ground water and seepage, water accumulated from overtopping waves, and mixed flows with sanitary sewage. Implementation of pump stations is generally considered after analysis of gravity outlets and detention storage, since the initial and continuous operational, maintenance, and power costs of the stations are commonly significantly greater than that of other measures. For areas where the interior and exterior flooding is highly dependent (high likelihood of blocked drains coincident with interior flooding), pumping may be the only means to significantly reduce interior flood losses. For areas with independent interior and exterior flood conditions and where coincident flooding is not likely, pumping facilities may not be required.

(2) Pumping station justification is part of the planning process. The feasibility of pumping stations is based on economic and other considerations. In general, the without pump condition (with gravity outlets and detention storage implemented) must indicate adverse effects under present and the most likely future conditions. The implementation of a pumping station must reduce the adverse effects sufficiently to justify the construction and operation of the facility. Finally, it must be demonstrated that the implementation of a pumping station is the most effective means of reducing the adverse effects.

(3) Pumping stations are normally located adjacent to the line-of protection. Normally a larger capacity station is more desirable than several smaller ones. The station should be aligned in a manner which enables direct flow patterns into the forebay from the conveyance channel or detention areas. Gravity outlets may be offset if located near pumping stations where sufficient direct flow access to both the pump and gravity outlets is unavailable.

(4) Hydrologic analyses for planning investigations normally provides hydrologic data to determine the feasibility, location, and total capacity of the pumping stations.

(5) Hydrologic analyses performed under design studies typically refine and detail the hydrologic results developed in the planning investigations. The number and types of pumps are determined to provide the total capacity developed in the planning study. Pump on-off elevations are specified. Pumping heads for efficiency and starting assumptions are specified for various combinations of interior and exterior stage conditions. Hydrologic analysis of pumping stations at the design level must be closely coordinated with other engineering design activities.

(6) First or operation floor elevations of pumping stations should be, as a minimum, at or above ground level to provide convenient access to equipment, eliminate need for protection against ground water, and to simplify the ventilation of the operation areas. The consequence of exceeding pump design stage must be evaluated.

(7) Pumping and gravity outlet effects on exterior stages and operation of other downstream gravity outlets should be considered in locating, sizing, and designing the pumping station.

(8) The pumping station capacity in urban areas is generally determined by the physical performance of the facility and its effect on flood damage reduction, costs, and environmental and social factors. Station capacities in rural (agricultural type damage) areas are more commonly based on economic optimization.

e. Intercepting Sewers or Channels. These conveyance systems interconnect two or more existing sewers or channels within the line-of-protection for the purpose of conveying their flows to gravity outlets, pumping stations, or pressure conduits, for combined discharge through the line-of-protection. Interceptor systems are designed to minimize the number of gravity outlets, pumping stations, and pressure conduits.

f. Pressure Conduits. Pressure conduits are pipes or closed conduits designed to convey interior flood waters through the line-of-protection under internal pressure. The inlet to the pressure conduit must be at a higher elevation than the river stage against which it functions. Some pressure conduits may serve as discharge lines for pumping facilities. The use of pressure conduits reduces the contributing interior runoff area and the magnitude and volume of flood waters that must be handled by other flood loss mitigation measures.

5-3. Physical Measures Remote From Line-of-Protection.

a. General. Measures are comprised of traditional structures such as channels, diversions, interior levees, and storage reservoirs remote from the line-of-protection. Their functional capability is therefore essentially the same as with any other planning or design investigations involving flood loss reduction measures. Consequently, only the interrelationship with other specific interior measures will be emphasized.

b. Channels. Conveyance channels reduce flood losses for damage centers remote from the line-of-protection and collect and transport runoff and other interior waters to gravity outlets, pumping stations, and pressure conduits. Where possible, channels should follow natural drainage and conveyance routes. When this is not possible, consideration should be given to locating channels near and parallel to the line-of-protection. Channels may be required in combinations with detention basins to connect with gravity outlets or pumping stations, and as exterior connections from the outlet works of gravity or pressure conduits or pumping stations to the river, lake, or ocean. The planning task is to approximately size and locate the channel system. The design task is to perform final design in terms of size, location, gradient, and auxilary control features of erosion protection and grade control.

c. Diversions. Diversions are used to transfer all or portions of the runoff from one location to another. Diversions may be made to collect flow for pressure conduits, to transfer flow out of the basin (reduce the contributing area), and to collect flow from areas to gravity outlets and pumping stations, thereby enabling fewer facilities. Diversions may be designed to permamently alter conveyance systems or to operate only for discharges above (and below) certain values. Diversions may be uncontrolled or operated as part of a coordinated system. Diversions may also be used to bypass flow around damage centers.

d. Remote Detention Areas or Reservoirs. Remote detention basins (reservoirs) have characteristics similar to those described for detention basins adjacent to the line-of-protection described in paragraph 5-2c. Bottomland detention basins may be natural sinks, oxbow lakes, or excavated sumps, or may be formed by levees. Hillside or bluff basins are really conventional reservoirs. Implementation of the remote basins may regulate flow to reduce the size of downstream interior flood loss reduction measures.

Damage reductions at several downstream locations may be achieved, in contrast to local protection works which are effective only at their individual damage center. Detention basins may also retain sediment from the hillside or bluff areas and thus eliminate it as an interior area problem.

e. Interior Levees and Walls. Interior levees and walls along conveyance channels may be implemented as local interior protection features. These barriers are normally lower in height than the conventional main levees and thus failure is less likely to result in catastrophic loss. If the barriers are of sufficient height, and damage potential from failure great, they are considered the same as the main line levees or walls. The interior levees may create secondary interior flooding problem that must be considered, though the magnitude would likely be minor. Implementation of these measures must meet criteria defined in Executive Order 11988" and other existing federal policy. Flood forecasting emergency-preparedness plans should be an integral part of implementation of interior levees and walls to reduce the potential for loss of life and property when the situation warrants. See criteria for main levees and walls described in paragraph 5-2a.

5-4. Nonstructural Measures.

a. Measure Categories. Nonstructural measures are categorized herein as:

(1) measures designed to permanently modify the damage susceptibility of existing structures,

(2) measures designed to manage future development and flood plain activities, and

(3) flood warning-emergency prepardness procedures. The measures warrant serious considerations in urban interior areas both as stand-alone measures and as a part of an integrated comprehensive plan.

b. Measures Which Permanently Modify Damage Susceptability of Existing Structures.

(1) Several types of nonstructural measures are designed to permanently modify damage potential of existing structures. They include: flood proofing (seals, earthen dikes, and walls); raising existing structures; and relocation of occupants and/or structures (damage potential) from the specified threatened area. The measures are designed to modify the damage potential of an area. They are typically implemented on a localized scale (such as neighborhood) as opposed to structural and other types of nonstructural measures which often are designed to function for larger areas.

(2) Flood proofing and raising of structures to target elevations protect structures and contents until design limits are exceeded. The measures, applied to individual or small groups of structures are generally less environmentally disruptive than structural alternatives. The measures do not reduce damage to vital services (i.e., water, gas, power), streets, bridges, and landscaping, and (in most cases) only slightly reduce the social

impact and disruption associated with flood events. Seals, walls and dikes are often significantly less reliable than other permanent measures.

(3) Permanent relocation is defined as the removal of inhabitants and damage potential from the identified hazard area. Included are the physical moving of a structure and contents from the flood plain or demolition of the structure and moving inhabitants and contents to a new structure off the flood plain. Demolition of the structure may not be required if a compatible flood plain use of the structure can be identified.

(4) Flood proofing, raising, and relocation actions are generally more economically justified than structural measures when only a few structures are involved. Similarly, implementing nonstructural measures to a few structures to permit increasing the size of a detention basin may be more attractive than increasing the size of gravity outlets or pumping stations.

c. Measures Which Manage Future Development.

(1) Management of future development reduces losses by requiring flood plain development and activities to be operated or located in a specific manner commensurate with the flood hazard. Land use development can be controlled by regulations such as zoning ordinances, building codes and restrictions, taxation, or purchase of land in fee or by purchase of a flood easement. Structures not precluded from flood plain locations by these measures may locate on the flood plain if constructed and maintained to be compatible with the recognized flood hazard.

(2) Regulatory actions and land acquisition can also bring about new use of the flood plain. The measures are attractive from the perspective of managing development to reduce the future damage potential of the area and utilization of the flood plain for compatible purposes.

(3) Measures which manage future development are generally compatible with implementation of other structural and nonstructural measures. Regulatory actions may be incorporated as part of the agreements with local agencies or the local sponsor. For example, implementation of regulatory policies to preserve the storage and functional integrity of detention basins over the life of the project may be employed.

d. Flood Forecasting-Emergency Preparedness Plans.

(1) Flood emergency preparedness plans are comprised of flood emergency management actions and activities that reduce flood losses and minimize social disruption and assist in recovery and reoccupation of flooded areas. The measures should not be considered in lieu of other feasible permanent structural or nonstructural alternatives due to their temporary nature and uncertain reliability during flood episodes. Preparedness plans, however, should be considered as interim measures until other flood loss reduction measures are implemented; as companions to, or enhancements of such other measures; and as a means of minimizing the risk of loss of life, flood damage and social disruption if other methods are not feasible.

(2) Flood forecasting-emergency preparedness plans are generally compatible with other structural and nonstructural flood reduction measures. Implementation is more frequent in urban interior areas than in agricultural interior areas. Implementation of some level of flood forecasting-emergency preparedness actions is usually feasible even if other structural and nonstructural measures are not.